Dr. STRANGELEAK

Or

How I Quit Leaking and Learned to Love the Bomb

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ABSTRACT

This presentation is a compilation of several papers and presentations directed toward the issue of Signal containment for Cable TV. This presentation will be subdivided into three categories:

1. What Can Leak, How Big Can They Get?
2. We Are Not Alone
3. The Residual RF Smog

Buried among these words will be some fact, presumption, hope and maybe a little humor. While our dedication to the issue of Signal Leakage, containment should be resolute, we should occasionally take a look at the big picture associated with the ever present issue of "Radiation".

INTRODUCTION

The potential of aeronautical interference by cable television has consumed vast amounts of ink, newspapers, magazines, legal briefs and the Federal Register have all reduced the issue to writing in the form of studies, objective analysis, sensationalism and regulations. Being against aeronautical safety is the implicit burden ascribed to anyone who is less than four square behind absolute containment of cable TV signals.

At the outset it is important to understand that all cable systems could generate (project) fields of about the same intensity from a catastrophic failure. Failures of this type are no more or less likely to occur from an old or new system or one that leaks a little or not at all.

What is not being said is the number of other devices and services capable of projecting fields in the aeronautical bands. This paper will identify some of these devices and compare their amounts of potential radiation to that of cable television. It is not the intent of this article to belittle the potential for calamity in the case of catastrophic failure of shielding integrity from cable systems. It is however intended to offer a fresh perspective on that degree of perceived safety lost by relaxing existing CATV leakage standards.

WHAT CAN LEAK AND HOW BIG CAN THEY GET?

What could leak in a system? One mile of system probably has:

5280'	of Distribution Cable
1600'	of Trunk Cable
6600'	of Activated Drop Cable
1	Trunk Amp
4	Line Extenders
3	Passives
40	Taps
72	Drops (.9x80) 44 Active
100	Trunk/Dist. Connectors
44	Elevated F Connectors (if trapped system x 2 or more)
132	Low Level F Connectors (2 at G/B one at conv.)

What then are the number of high level radiation opportunities versus those at low level?

High Level
Exposed to trunk or distribution levels

- 6880' of cable
- 5 amp housings
- 3 passive housings
- 40 tap housings
- 100 connectors

Low Level
Exposed to drop levels

- 6600' of activated drop cable
- 176 connectors

It is interesting to note that in our model system the high level system is about the same as the low level in feet of activated cable as well as connector interfaces.

In a typical 150 mile aerial system, 453 system leaks and 1086 drop leaks were found.

When a drops level is around 10 dbmv on average and the levels in trunk distribution are around 30 dbmv the difference in levels is 20 db. Twenty db represents a voltage ratio of 10, consequently the equivalent microvolt per meter contour would project 10 times further theoretically from the source of leakage driven at +30 dbmv than the same contour from the source driven at +10 dbmv. Likewise the area within the given microvolt per meter contour will increase by 10^2 or 100. The impact of 453 system leaks illuminating areas 100 times greater results in 453 system leaks being 42 times more significant than the 1086 drop leaks.

(453 x 100/1086 = 41.7)

It becomes obvious that the greatest impact on system leakage will come from maintenance of the distribution plant and not the system drops.

HOW BIG CAN IT GET?

Consider a distribution line operation at +42 dbmv. The power at this point may be calculated:

$$+42\ \text{dBmv} = \text{Log}_{10}\left(\frac{42}{20}\right) / 1000 = .125\ \text{Volts}$$

$$P = \frac{E^2}{R} = \frac{.125^2}{75} = .0002\ \text{Watts}$$

Assume that one half of this power is radiated istropically from a leakage source resulting in a source power of 100 microwatts.

$$P = \frac{P_t}{4\pi(R)^2} = \frac{100 \times 10^{-6}}{12.56 \times (3)^2} = 884 \times 10^{-9}\ \text{Watts}$$

$$E = \sqrt{WR} = \sqrt{884 \times 10^{-9} \times 377} = 18,000\ \text{uV/m}$$

Under these proposed conditions a leakage field of 18,000 uv/m would be present at 3 meters. That ain't hay!

While cable television may leak and conceivably leak a lot, cable retains control over the frequencies of its emission. Under the present and proposed standards these frequencies remain offset from channels of aeronautical usage.

It is elementary radio science that a higher level of leakage is necessary for an offset frequency to cause air space interference than for a non-offset frequency. From this, one might logically conclude frequency avoidance can provide all the caution necessary to safeguard aeronautical operations.

The second point of concern is when the leakage from a cable system interferes with services having exclusive and valid use of the airwaves on frequencies used within the "closed" cable spectrum. The distinction is, cable leakage rules in this regard do not stop with objective limits imposed by standards, such as this many microvolts per meter at this distance, but impose an additional and logical burden on CATV systems to take whatever steps are necessary to limit actual interference. This fact should not be overlooked when terrestrial users speak out against "relaxed" leakage standards.

WE ARE NOT ALONE

Many other devices and services are capable of projecting incidental radio fields.

In the following tables the permitted fields from the various devices are graphically compared to the allowable emission of cable television in the same portion of the spectrum.

The Federal Communications Commission maintains an ongoing record of complaints alleging interference to various services. These records are anaylzed by the development of a matrix showing the number of complaints reported from a particular service into another. Tables (1&2) show the record of such reports for the period of 1982 thru part of 1984. The various services are represented by numbers that generally correspond to the portion of the Federal Regulations that control the service.

The following guide should be used in reading tables (1&2):

Part	Description of Service
15	Radio Frequency Devices
18	Industrial, Scientific, Medical
21	Domestic Public Fixed Services
69	Home Electronics (TV,Radios,Etc.)
73	Broadcast Services
76	Cable Television Service
81	Maritime
83	Shipboard
87	Aviation
89	Safety Land Mobile
91	Industrial Land Mobile
93	Land Transportation
94	Private Operational Fixed
95	Personal Radio Service
97	Amateur Radio Service
G	Governmental
Other	Not Defined

Table 1

FEDERAL COMMUNICATIONS COMMISSION
FIELD OPERATIONS BUREAU

FIR002

REPORT OF INTERFERENCE COMPLAINTS RECEIVED
** NATIONAL SUMMARY **
CUMULATIVE - FY1982

FROM \ TO	15•••	18•••	21•••	69•••	73•••	76•••	81•••	83•••	87•••	89•••	91•••	93•••	94•••	95•••	97•••	G••••	OTHER	TOTAL
15•	28	1	4	5432	10	15	10	0	2	45	20	2	0	47	86	4	20	5726
18•	1	0	0	278	3	2	0	0	0	5	4	0	0	26	4	3	1	327
21•	1	1	75	143	1	4	1	1	1	23	26	7	1	7	15	6	8	321
69•	18	0	2	26	3	1	0	0	0	4	3	1	0	9	3	0	2	72
73•	8	0	2	1691	205	18	3	3	24	19	59	2	0	4	29	23	59	2149
76•	4	0	0	1156	4	34	1	1	2	9	5	0	0	1	86	4	21	1328
81•	2	0	0	15	0	0	67	34	0	6	7	4	0	0	1	16	5	157
83•	0	0	1	8	0	0	54	260	3	10	9	0	0	0	3	100	2	450
87•	1	0	0	37	2	0	1	1	129	2	1	0	0	0	2	18	0	194
89•	4	0	7	85	2	3	5	3	1	637	28	4	0	6	9	13	5	812
91•	10	0	27	268	3	3	4	3	2	166	2919	29	0	10	19	25	14	3503
93•	1	0	3	26	3	0	1	2	1	9	45	260	0	1	5	7	3	367
94•	0	0	0	2	1	1	0	0	0	0	0	0	4	0	0	0	0	8
95•	68	3	3	42263	14	96	3	0	2	25	39	10	0	4537	51	9	160	47283
97•	13	0	6	2489	2	10	2	0	3	20	16	3	0	11	1323	34	16	3948
G••	1	0	0	26	3	0	18	11	7	3	2	3	0	4	18	50	10	156
OTHER	55	4	28	6870	65	92	124	51	84	241	308	54	1	90	358	249	176	8850
TOTAL	215	9	158	60815	321	279	294	370	261	1224	3491	379	6	4753	2012	562	502	75651

FEDERAL COMMUNICATIONS COMMISSION
FIELD OPERATIONS BUREAU

FIR002

REPORT OF INTERFERENCE COMPLAINTS RECEIVED
** NATIONAL SUMMARY **
CUMULATIVE - FY1983

FROM \ TO	15•••	18•••	21•••	69•••	73•••	76•••	81•••	83•••	87•••	89•••	91•••	93•••	94•••	95•••	97•••	G••••	OTHER	TOTAL
15•	90	0	8	4307	3	33	0	0	1	40	33	4	0	12	116	6	15	4668
18•	1	1	0	35	0	2	0	0	1	0	7	1	0	11	9	3	1	72
21•	3	0	48	127	1	0	5	4	1	27	32	12	0	10	7	17	3	297
69•	4	0	0	24	2	0	0	0	0	2	2	0	0	24	6	0	2	66
73•	19	0	2	1719	188	14	6	2	14	14	35	0	0	1	27	45	32	2118
76•	1	0	1	1133	1	49	2	0	0	12	2	1	0	1	105	2	4	1314
81•	0	0	0	7	0	0	56	24	0	5	0	3	0	0	3	16	0	114
83•	0	0	8	15	1	0	42	205	5	27	4	2	0	0	22	91	2	424
87•	0	0	0	41	2	0	1	1	128	0	0	0	0	1	0	21	2	197
89•	0	0	6	61	0	2	2	5	1	503	26	2	0	1	10	8	6	653
91•	5	0	10	215	4	2	0	1	2	113	2683	25	0	0	13	27	11	3111
93•	3	0	0	34	0	0	1	1	0	6	32	222	0	0	7	4	1	311
94•	1	0	0	7	0	0	0	0	0	0	0	0	3	0	0	0	1	12
95•	78	0	12	36517	17	130	2	0	3	27	25	1	0	4075	46	9	79	41021
97•	27	0	2	2679	2	34	2	0	5	7	13	1	0	4	1273	18	26	4093
G••	0	1	0	27	0	0	19	15	7	4	3	2	0	1	24	58	10	171
OTHER	61	2	41	5518	42	108	90	50	127	223	315	41	4	79	410	1904	222	9237
TOTAL	293	4	138	52486	263	374	228	308	295	1010	3212	317	7	4220	2078	2229	417	67879

Table 2

FEDERAL COMMUNICATIONS COMMISSION
FIELD OPERATIONS BUREAU

FIR002

REPORT OF INTERFERENCE COMPLAINTS RECEIVED
** NATIONAL SUMMARY **
FIRST QUARTER - FY1984

FROM \ TO	15***	18***	21***	69***	73***	76***	81***	83***	87***	89***	91***	93***	94***	95***	97***	G****	OTHER	TOTAL
15*	17	0	0	873	4	6	1	0	0	4	4	0	0	6	18	2	0	935
18*	0	0	1	13	0	1	0	0	0	0	0	0	0	3	1	0	0	19
21*	2	0	6	35	0	0	0	0	0	4	5	3	0	0	0	4	2	61
69*	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	1	8
73*	5	0	1	332	42	5	2	0	2	4	8	0	0	3	8	5	9	426
76*	0	0	0	254	1	10	0	0	1	1	1	0	0	1	39	0	1	309
81*	0	0	0	0	0	1	23	3	0	0	0	0	0	0	1	0	0	28
83*	0	0	0	4	0	0	13	44	1	2	3	0	0	0	3	31	0	101
67*	0	0	0	6	1	0	1	0	23	0	0	0	0	0	0	6	0	37
69*	2	0	1	13	0	0	0	0	1	124	2	0	0	1	1	0	2	147
91*	0	0	4	57	1	0	0	1	0	30	623	7	0	1	6	2	4	736
93*	0	0	0	14	0	2	1	0	0	2	2	54	0	0	3	1	0	79
94*	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
95*	36	0	2	10103	5	22	0	0	0	3	5	0	1	877	7	0	7	11068
97*	13	0	0	689	1	5	1	0	0	3	6	0	0	1	316	4	1	1040
G**	1	0	0	8	1	1	3	5	0	1	2	0	0	0	8	18	2	50
OTHER	13	2	4	1242	13	11	27	8	69	49	76	7	1	10	89	544	181	2346
TOTAL	89	2	19	13650	69	64	72	61	97	227	737	71	3	903	500	617	210	17391

FEDERAL COMMUNICATIONS COMMISSION
FIELD OPERATIONS BUREAU

FIR002

REPORT OF INTERFERENCE COMPLAINTS RECEIVED
** NATIONAL SUMMARY **
SECOND QUARTER - FY1984

FROM \ TO	15***	18***	21***	69***	73***	76***	81***	83***	87***	89***	91***	93***	94***	95***	97***	G****	OTHER	TOTAL
15*	22	1	1	1539	1	1	0	0	0	7	0	0	0	3	21	0	1	1597
18*	0	0	0	18	1	0	0	0	0	0	0	1	0	4	0	0	0	24
21*	1	0	7	41	0	2	1	0	0	12	13	3	1	3	3	3	0	90
69*	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	4
73*	6	1	1	518	59	1	2	0	6	6	8	2	0	1	7	8	1	627
76*	0	0	0	366	1	6	1	1	0	3	0	0	0	5	33	2	0	418
81*	0	0	0	1	0	0	8	2	0	1	0	0	0	0	0	1	0	13
83*	0	0	0	1	0	0	10	49	0	4	1	0	0	0	9	20	0	94
87*	0	0	0	8	0	0	0	0	10	0	0	0	0	0	0	5	1	24
89*	0	0	1	21	0	1	2	0	0	88	8	1	0	0	4	0	0	126
91*	1	0	0	173	2	2	0	0	1	17	673	0	0	4	4	4	1	882
93*	0	0	0	17	0	0	1	0	0	0	7	49	0	1	3	0	0	78
94*	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	3
95*	14	1	0	9725	7	13	0	0	1	4	35	0	0	1155	6	2	0	10963
97*	12	0	0	739	1	9	0	0	0	4	2	0	0	3	384	5	4	1163
G**	1	0	0	8	0	0	3	6	0	2	7	1	0	0	7	18	2	55
OTHER	26	3	4	1570	5	6	21	16	63	43	65	10	1	9	81	793	42	2758
TOTAL	84	6	14	14748	77	41	49	74	81	191	819	67	3	1189	562	861	53	18919

It is not intended to be implied that each of the various devices actually project fields of the indicated amounts but to identify the limit imposed on these services by the Commission. Conversely under some circumstances the fields of these devices may actually exceed the standards. This can occur thru enhancement brought about by the introduction of gain providing elements not found under the conditions specified in the Commission testing routine. An example of enhancement might be the Local Oscillator of an FM receiver being introduced to the gain of a directional antenna. Excision of the standard can also occur thru defect, many of the items shown are consumer devices which may be subject to negligent repair, misapplication or gradual deterioration resulting in emissions greater than the standard. No one routinely looks after the emission from these devices until an incident and investigation brings to bear technical scrutiny, these things keep humming along for years. The following tables are divided into two categories:

Category I (Table 3)

Transmitting facilities whose permitted incidental emissions are specified relative to the main carrier. In these cases the power of the evaluated device is shown and the permitted power in watts represents the power level of the permitted incidental output.

Category II (Table 4)

Incidental emitters such as radios whose intended purpose is not to transmit or if transmitting services those whose incidental fields are specified as intensity at a prescribed distance.

Because Cable Television leakage standards are given in field intensity it has been necessary to relate these values back to power for comparison to the category one devices. This was accomplished by traditional techniques. Also the assumption is made the source power will radiate isotropically.

Some of the Category 2 devices have been modified by Linear Conversion to reflect the anticipated level at 10 feet from the source. This is necessary to relate them to the Cable field intensity from 54 to 116 MHz which is also given at 10 feet. Further cable intensity below 54 and above 216 MHz is represented at 10' thru correcting by linear conversion the standard which is given at 100'.

In a close call one could question the assumptions and conversion practices shown herein but these are not close.

The first line of Table 3 shows a category I FM station. Where the permitted power in watts is 252 Billion times that of Cable TV.

These tables graphically illustrate the fact that cable has been given standards that do not "fit" with the other potentially hazardous sources and further demonstrates a lack of overall Federal policy in the area of incidental emissions.

The assumptions and calculations necessary to develop these tables are too numerous to include here. For a more comprehensive understanding of the processes used in the preparation of this report, the reader is invited to contact the author

THE RESIDUAL RF SMOG

A further source of signal leakage is present from a cable system. A certain cloud of signal leakage remains in many cable systems which is beyond the control or apparent liability of the cable operator. This "background count" is a function of the radiation of cable system frequencies by subscriber devices attached to the system. These devices may be subdivided into two classes:

a. Purposeful system operation

b. Signal misappropriation

When a cable system uses a converter as a channel selection device before a subscriber's receiver, a secondary benefit is obtained. The converter serves as the termination of the subscribers drop. This termination is under the operator· control and always achieved in shielded coaxial cable. The opportunity for leakage is no more than any other coaxial junction. When any class or tier of service is relayed directly to the television receiver the termination becomes the input of the TV tuner which generally is highly reactive (a bad match). This coupled with propensity to use open feed lines within the television from the antenna terminals to the actual tuner input, all set up an opportunity for signal leakage. Additionally a television, while already a bad match will be an even worse match on signals to which it is not tuned. This likewise is true of FM receivers which are notorious for signal radiation. The leakage of cable signal components from these points can represent a substantial portion of the "background noise" from an operating system. Strictly on point with careful scrutiny of the FCC Rule 76.617 one could decide this leakage is not the responsibility of the cable operator.

Category I

Table 3

Type of Service or Device	Detail	Rule Cite	Permitted[*1] Emission (watts)	Converted[*2] Cable Emission (watts)	Differential[*3]
FM Broadcast	100kw @ 107.9MHz	73.317 (13)	3×10^{1}	$1.19X10^{-10}$	252 Billion
FM Broadcast	100kw 88-107.5MHz	73.317(14)	1×10^{-3}	$1.19x10^{-10}$	8.4 Million
VHF Television	Low Band 100kw	73.687	$1x10^{-1}$	$1.19x10^{-10}$	840 Million
VHF Television	High Band 316kw	73.687	$3x10^{-1}$	$1.19x10^{-10}$	2.52 Billion
Low Power TV	1 Watt VHF	74.736	$1x10^{-3}$	$1.19x10^{-10}$	84 Million
Low Power TV	90 Watt VHF	74.736	$5x10^{-4}$	$1.19x10^{-10}$	4.2 Million
Low Power TV	100 Watt VHF	74.736	$1x10^{-4}$	$1.19x10^{-10}$	840 Thousand
Amateur Radio	1000 Watts	97.73	$1x10^{-3}$	$1.19x10^{-10}$	8.4 Million
Amateur Radio	25 Watts	97.73	$2.5x10^{-3}$	$1.19x10^{-10}$	21 Million
Private Radio	350 Watts	90.209	$5x10^{-4}$	$1.19x10^{-10}$	4.2 Million
Aeronautical (ground station)	100 Watts	87.71	$1x10^{-4}$	$1.19x10^{-10}$	840 Thousand
Aircraft Transmitters	10 Watts	87.71	$5x10^{-4}$	$1.19x10^{-10}$	4.2 Million

*1 By application of the requirement to the operational level shown in the detail column.
*2 By conversion of Rule 76.605 a(12) to power in the Band 54-216MHz
*3 Ratio of power difference

Category II

Table 4

Type of Service or Device	Detail	Rule Cite	Permitted[*1] Field at 3 Meters	Cable Field at 3 Meters	Differential[*2]
Radio Receivers (Radio,TV,Etc.)	Tuning 30 to 890 MHz	15.63	1500 uv/m	20 uv/m	75
Cordless Phones	49 MHz	15.118	500 uv/m	20 uv/m	25
Wireless Mikes (Etc.)	above 70 MHz	15.120	1500 uv/M	20 uv/m	75
Transmitter	72-76 MHz	15.359	1500 uv/m	20 uv/m	75
VCR/Video Games	88-216 MHz	15.610	150 uv/m	20 uv/m	7.5
Class A Computers	Systems	15.810	500 uv/m	20 uv/m	25
Class B Computers	Home Units	15.830	150 uv/m	20 uv/m	7.5

*1 Worst case 54 to 216 MHz converted to 3 meters as necessary

*2 Ratio of field intensity difference

Practically the cable system will be held accountable for these sources.

The second phase of the RF Smog problem comes from signal misappropriation. This class included:

* Bootleg second sets using marginal hardware and/or bad installation practices.

* Activation of twin lead internal wiring systems.

* Siphoning of FM signals with bad hardware.

* Internal antennas inadvertently reattached.

If systems deliver signals without converters and the levels are kept close to the minimum (around Odbmv) the radiation will be also at minimum. There will be a direct relationship between the signal input and the radiated field. A rough approximation of the magnitude of signal radiation by television receivers can be made by surveying a system using converters for leakage on the converters output frequency. For this method to be effective the output channel must be free from over the air reception and the survey device must cover a sufficiently wide spectrum to include the accumulated error of the individual channels being received and the heterodyne accuracy of the individual set top. The cable channel which corresponds to the convertor channel output must either be accurately identified and discounted or suspended during the actual survey period. Present Commission standards prescribe convertor delivery accuracy at plus or minus 250 KHz of the nominal visual frequency. This technique will not pick up radiation from devices connected directly to the cable without the convertor.

CONCLUSION

More heat than light has been brought to the issue of Signal Leakage. Until the rules related to Signal Leakage are borne of study and not reaction, Dr Strangeleak will keep hanging around. We as an industry are on the right track but we must continue our efforts along the lines of seeking equitable regulation, applying peer pressure to those who lag behind in leakage maintenance and ever important, keeping our system clean and tight.